



NATO Code of Best Practice (COBP) for C2 Assessment

Formulating the Problem and the Strategy for Solution

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Notes for Slide 2

In this talk, I will be covering the two aspects of Problem Formulation and Solution Strategy, which are covered in Chapters 3 and 4 of the new Code of Best Practice.

Many contributors across NATO involved in C2 assessment have given of their time to produce these chapters.

They represent completely new material, compared to the previous version of the NATO Code of Best Practice, and help to place the analysis of such complex issues within a broader context.



Problem Formulation

- “First find out what the question is – then find out what the *real* question is” – Vince Roske



Notes for Slide 4

The essence of Problem Formulation is to find out what are the real issues which lie behind the question which is put to the study team.



Problem Formulation - Why Do It?

- Effective problem formulation is fundamental to the success of all analysis
- In C2 assessment the problems are often ill-defined and complex, involving many dimensions and a rich context
- The problem formulation phase should identify the Context of the Study and aspects of the Problem related issues - the **what and the why**

Notes for Slide 6

- Effective problem formulation is fundamental to the success of all analysis, but particularly in C2 assessment because the problems are often ill-defined and complex, involving many dimensions and a rich context. Problem formulation involves decomposition of the analytic problem into appropriate dimensions such as structures, functions, mission areas, command echelons, and C2 systems.
- Within the whole study context, we are attempting at this first stage to understand what the problem really is and why it is important - the WHAT and WHY of the study.
- The problem formulation phase should identify the **Context** of the Study and aspects of the **Problem related issues**.



Problem Formulation - Context

- Geopolitical context that bounds the problem space
- Aim and Objectives of the analysis
 - including the decisions to be supported
- Generic C2 issues
- Relevant previous studies

Notes for Slide 8

- The Context of the Study includes:
 - Geopolitical context that bounds the problem space;
 - political, social, historical, economic, geographic, technological;
 - actors;
 - threats.
 - Aim and Objectives of the analysis;
 - including the decisions to be supported
 - Generic C2 issues;
 - Generic C2 issues include for example, key systems, doctrine, TTP, organisational structures, and key assumptions (e.g. system performance parameters)
 - Relevant previous studies.



Problem Formulation - Aspects of the Problem

- Issues to be Addressed
- Assumptions
- High Level Measures of Merit (Outputs)
- Independent Variables (Inputs) (controllable and uncontrollable)
- Constraints on the Values of the Variables (domain and range)
 - *The problem is not formulated until the Assessment Team has specified each aspect of the problem.*

Notes for Slide 10

The Aspects of the Problem include:

- Issues to be Addressed;
- Assumptions;
- High Level MoM;
- Independent Variables (controllable and uncontrollable); and
- Constraints on the Values of the Variables (domain and range.)

The problem is not formulated until the Assessment Team has specified each aspect of the problem.

In Simple Terms.....

- Begin with the real problem
- Identify the variables bounding the problem space
- Determine which are outputs (dependent)
- Determine which are inputs (independent)
- Build an understanding of how these relate

– A voyage of discovery

Notes for Slide 12

In simple terms, problem formulation can thus be seen as an iterative process.

First, the Team must identify the variables that bound the problem space.

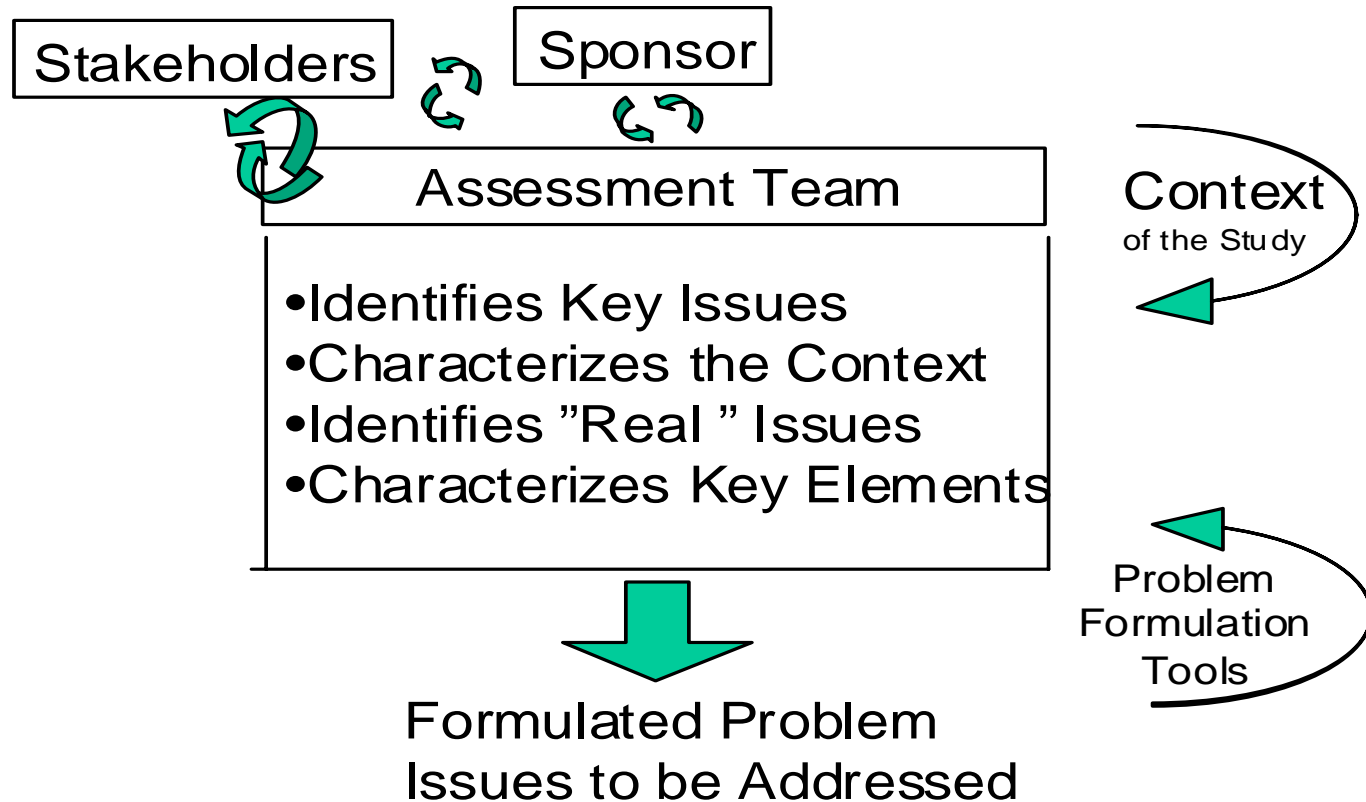
Then they must determine which of these are outputs (dependent variables) and which of these are inputs (independent variables).

The team proceeds by iterating to build an understanding of how these relate to each other. It should be viewed as a voyage of discovery. In most, if not all cases of C2 assessment, the knowledge domain under study is in fact a system characterised by rich interaction and feedback among all the factors of variables of interest. The choice of dependent variables results from a clear specification of the issues and products needed to satisfy the terms of reference. Independent and intervening variables are also chosen based on the purpose of the analysis.

In the initial problem formulation iteration, it is critical to begin with an understanding of the REAL problem rather than a determination to apply readily available tools, scenarios, and data.

Interaction and Feedback

Problem Formulation Process



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This shows the process in diagrammatic terms as a close set of interactions between the stakeholders (those with an interest in the results of the study), the sponsor of the study (with a direct interest and probably also responsible for funding the study) and the study team.

This interaction takes into account the political/military/economic etc. contexts of the study, and applies appropriate problem formulation tools to help in the analysis. These tools will be different (in general) from those 'solving' models and tools used later in the study process.

Principles of Problem Formulation

- Do it before developing concepts for analysis or model selection
- Understand the decisions to be supported and stakeholder viewpoints
- Carefully review previous work
- Do analysis *and* synthesis
- Be broad and iterative
- Practical constraints are modifiers not drivers
- Address risks to the study explicitly



Notes for Slide 16

Explicit problem formulation must precede construction of concepts for analysis or method selection. Especially in C2 assessments, this is not a trivial exercise. Proper resourcing is essential.

An understanding of the decisions to be supported by the analysis and the viewpoints of the various stakeholders (e.g., customers, users, and suppliers) is essential to clarifying the study issues.

A careful review of previous work must be carried out as a valuable source of ideas, information, and insight.

Problem formulation must not only analyse (dissect), but also provide a clear and valid mechanism for meaningful synthesis to yield coherent knowledge about the original, larger problem.

It must be broad and iterative in nature, accepting the minimum of *a priori* constraints and using methods to encourage creative and multi-disciplinary thinking. Change is inevitable in many dimensions. Thus the assessment process must anticipate this change and accommodate it.

Practical constraints such as data availability, study resources (including time) and limitations of tools should be treated as modifiers on the problem formulation rather than initial drivers. Problem Formulation should address risk from multiple perspectives. In addition to sensitivity analysis of the dependent variables, risk analysis techniques should be used to directly explore options to mitigate risk.

Proper Problem Formulation takes substantial time and effort!



Additional Principles for OOTW C2 Assessment

- Address the Geopolitical Context and generic C2 issues
- Look at Policy level impacts - MoPE
- History can be important
- Do not focus in too soon

A broad range of disciplines (e.g. social scientists, historians, and regional experts in OOTW assessment) is required

Notes for Slide 18

Problem formulation must address the geopolitical context of the problem and seek to identify the “generic” C2 issues contained within the terms of reference for the study.

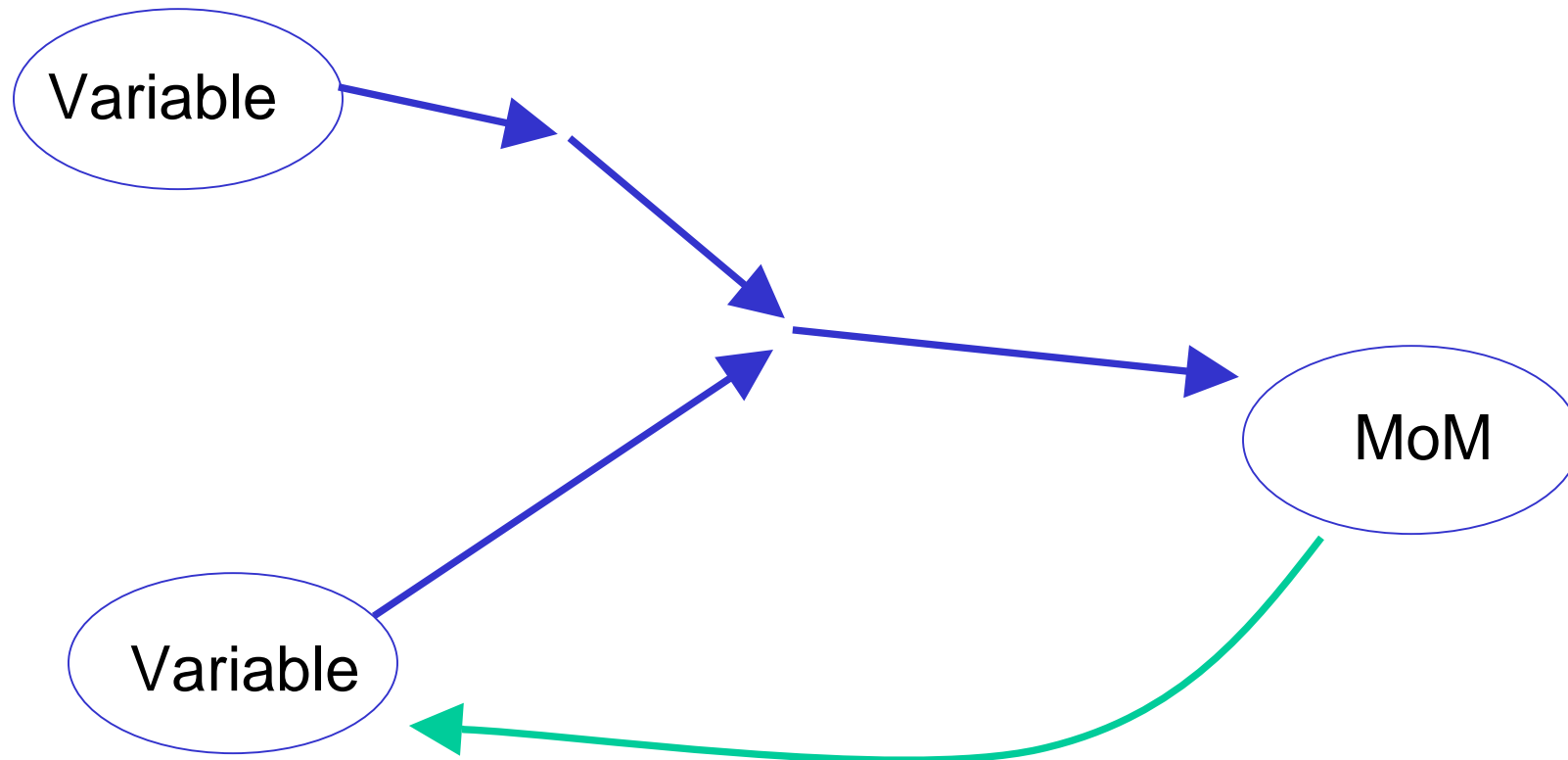
OOTW C2 assessments often involve policy-related impacts outside the context of a particular military operation. Therefore, MoM hierarchies must contain measures of policy effectiveness.

An historical perspective is critical to understanding OOTW because social conflict, and structures often have roots far back in history. However, it must be remembered that present-day social behaviour is not driven by historical events themselves, but by present-day perceptions, processes, and prejudices which have evolved from the past.

A key risk in complex OOTW studies is allowing the problem formulation process to focus in prematurely on subsets of the problem because they are: a) interesting; b) familiar; c) pre-judged to be critical; d) explicitly called out by the customer or e) easy to analyse. This requires great discipline by the study team, especially where the team’s previous experience is biased in favour of particular parts of the problem space.

The Assessment Team needs access to subject matter experts from a broad range of disciplines (e.g. social scientists, historians, and regional experts in OOTW assessment.)

Chains of Cause and Effect

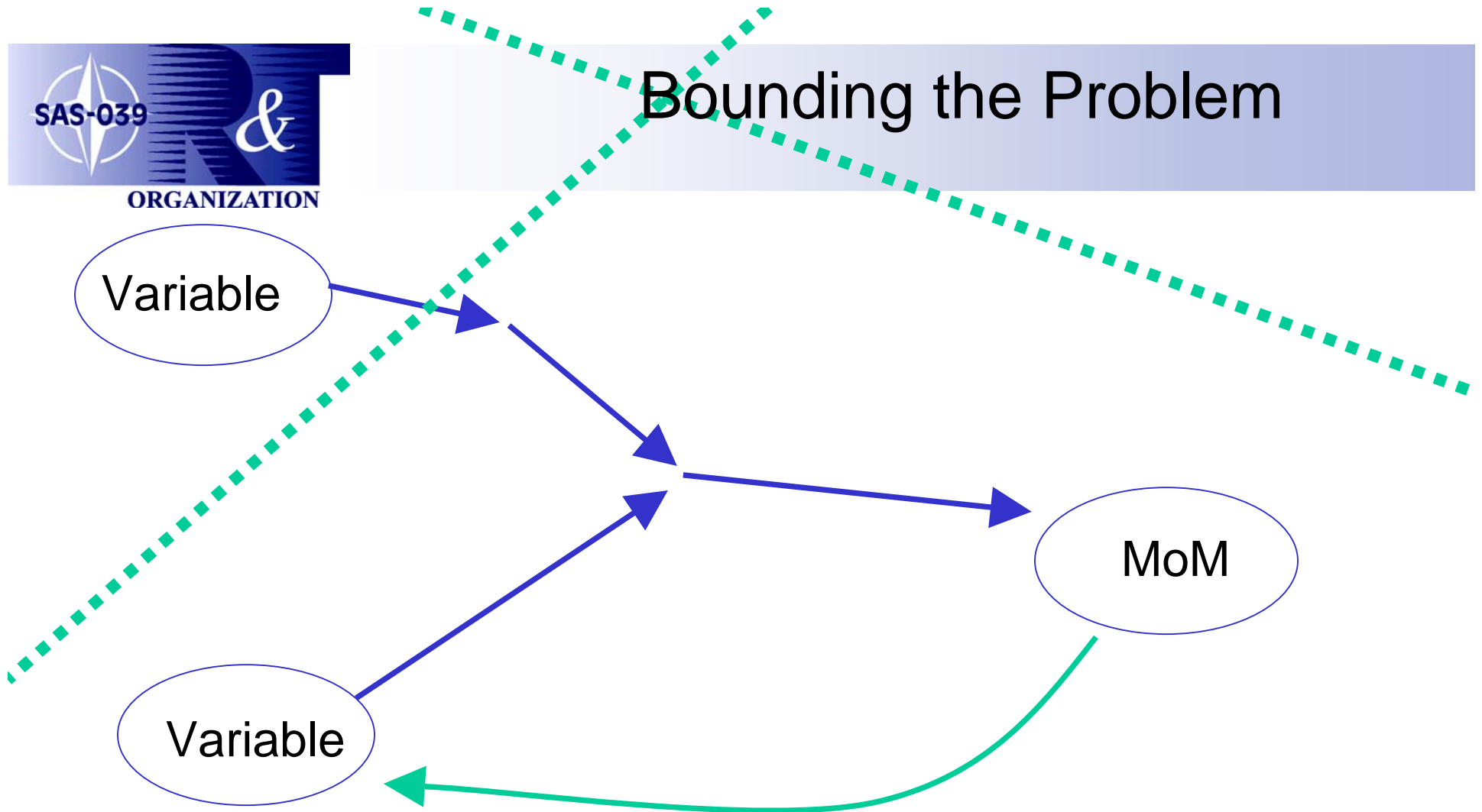


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During the early stages of Problem Formulation it is important to quickly cover the whole problem and produce an initial formulation (i.e., an explicit expression of the problem). This prevents premature narrowing of the assessment and serves as an aid to shared situation awareness within the study team. A good approach is to use influence diagrams such as the one shown here.

In formulating an OOTW problem we are trying to bound a complex system. This is partly a process of understanding boundaries which exist in reality (such as Mission Statements and Geographical Areas) and partly imposing artificial boundaries in order to illuminate the structure of the problem and constrain the scope of the analysis.

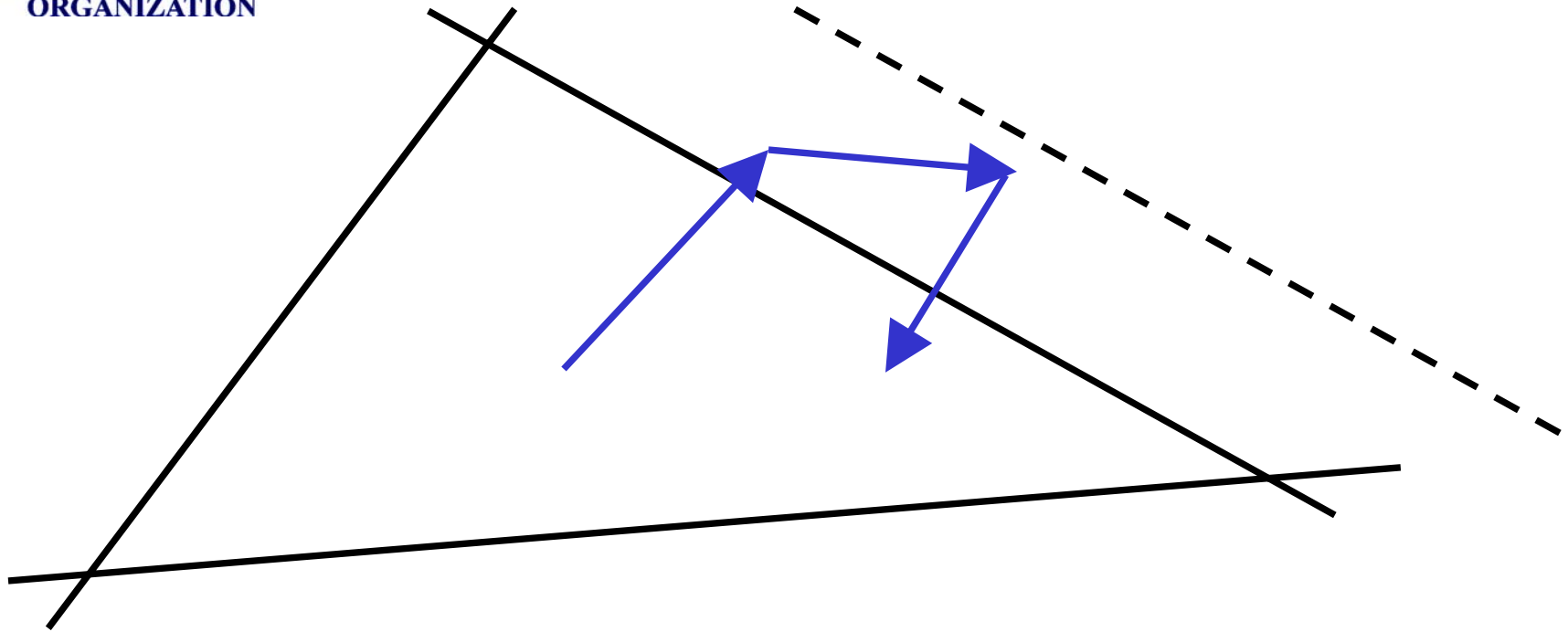
Bounding the Problem



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In dealing with fuzzy or uncertain boundaries, the problem formulation process needs to explore and understand the significance of each boundary before making (or seeking from customers) assumptions about it. This involves keeping an open mind, during the early stages of problem formulation, about where the boundaries lie and their dimensional nature. This is difficult because it makes the problem modelling process more complicated. A call for hard specification too early in the problem formulation process must be avoided. In the end, of course, the problem must be formulated in order to solve it, but formulation should be an output from the first full iteration, not an early input to it. The danger is that we exclude dimensions from the analysis which turn out to be important later.

Bounding the Problem



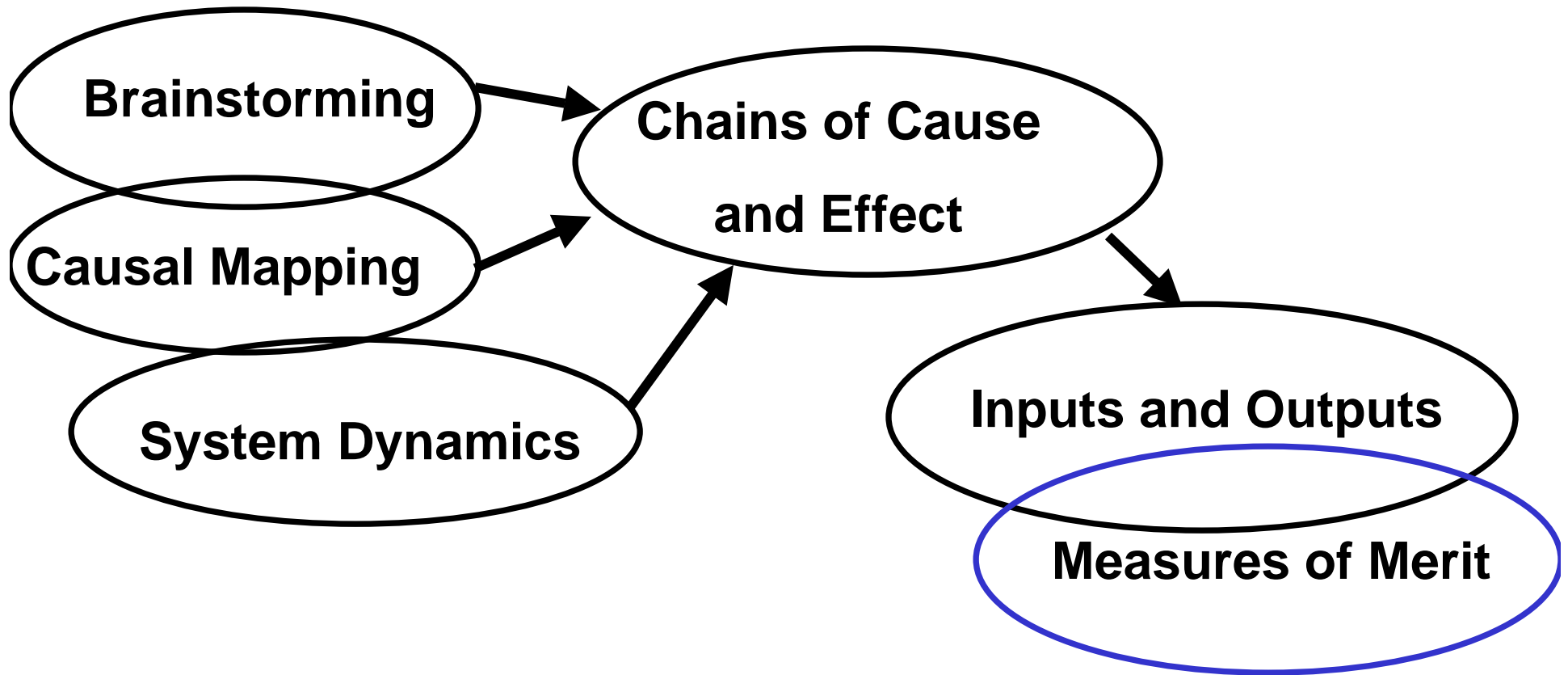
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Boundaries (especially self-imposed ones) should be kept porous, allowing for cause and effect chains as shown here, to flow through the external environment of the (partial) complex system that the boundaries define.

Problems where the chains of cause and effect go outside the boundary and then back in are particularly difficult to cope with.

While clear definitions and hard conceptual boundaries are ultimately necessary in order to constrain the problem space into a manageable form, care must be taken to avoid coming to closure prematurely.

Development of High Level MoM

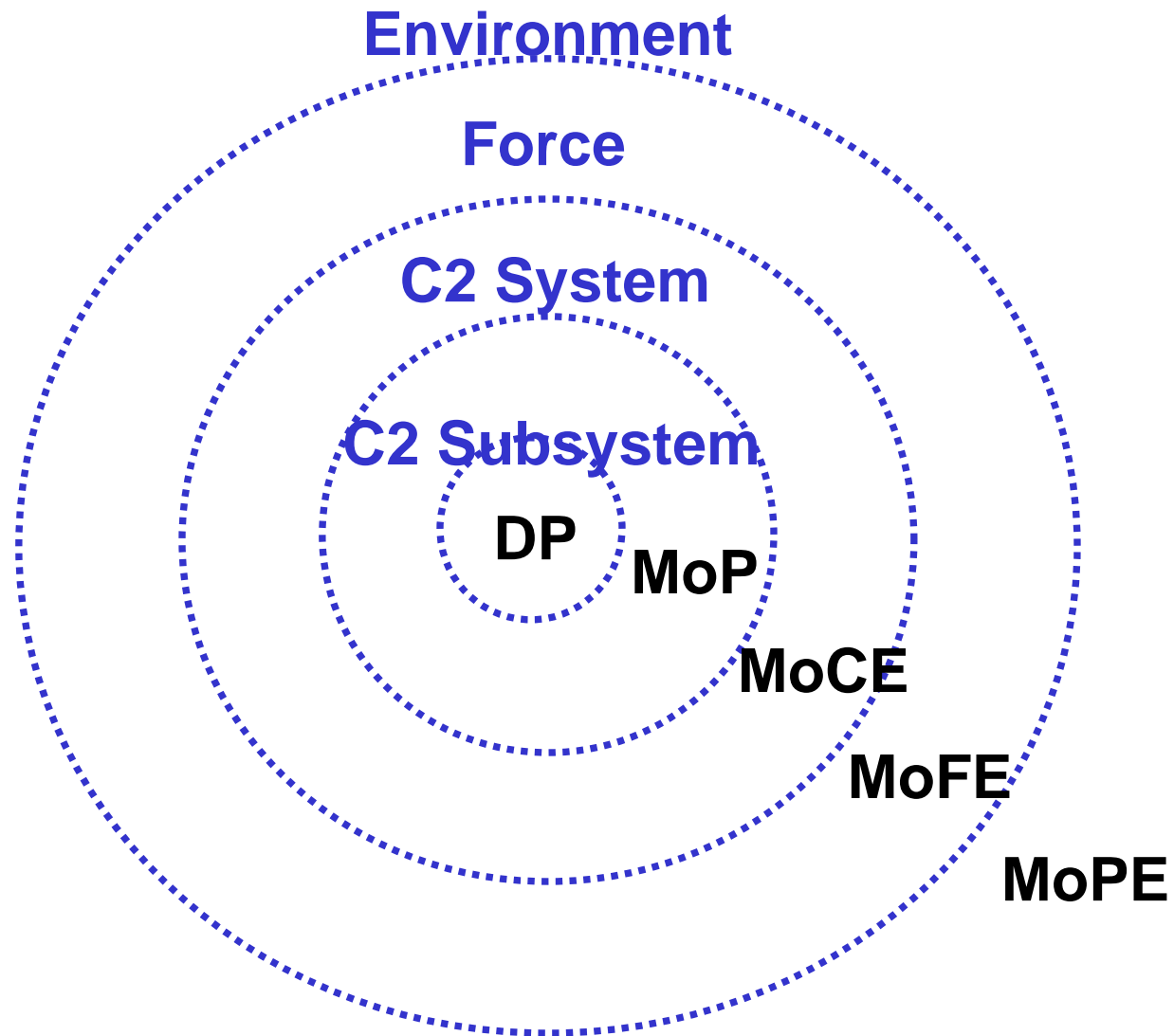


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Identification of high level MoM should start with ideal measures of the desired benefits before considering what can be practically generated by analysis (the latter may force the use of surrogate MoM, but these must be clearly related to the desired measures).

A structured analysis of potential benefits should be carried out as a basis for constructing appropriate Measures of Merit (MoM). Mapping techniques (such as cognitive and causal mapping) are a good way to express the various relationships within the problem space and to identify 'chains' of influence (as shown here). These lead on to resultant structure in terms of independent and dependent variables, and hence to high level MoM.

A Structured Analysis of Measures of Merit



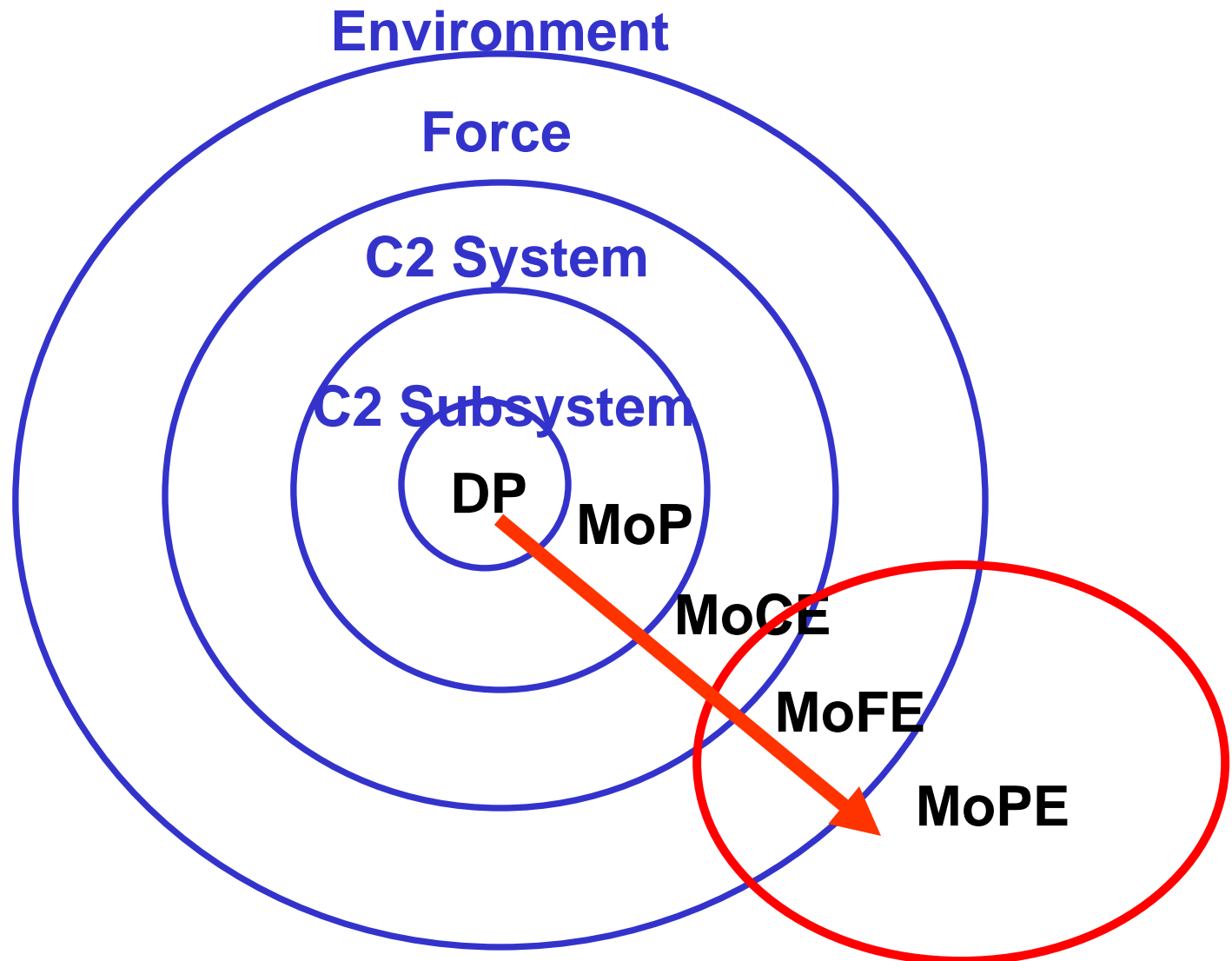
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The structured analysis of benefits is a logical process that seeks causally to map lower level Measures of Merit that can be related to investments or other actions to higher level Measures that can be valued directly by decision-makers.

As shown here, we can consider such measures of Merit as forming a set of expanding circles going from the C2 subsystem to the Force and the environment.

This corresponds to a hierarchy of Measures of Merit ranging from Performance through C2 Effectiveness to Force Effectiveness and Policy Effectiveness.

A Structured Analysis of Measures of Merit





Notes for Slide 30

In the initial problem formulation, we should focus initially on the higher level end of this set of Measures of Merit, with the more detailed Measures being considered later in the Study process.



Tools for Problem Formulation

- Elicitation support
- Influence diagrams
- Causal maps
- System dynamic models
- Agent based 'distillations'
- Etc

Notes for Slide 32

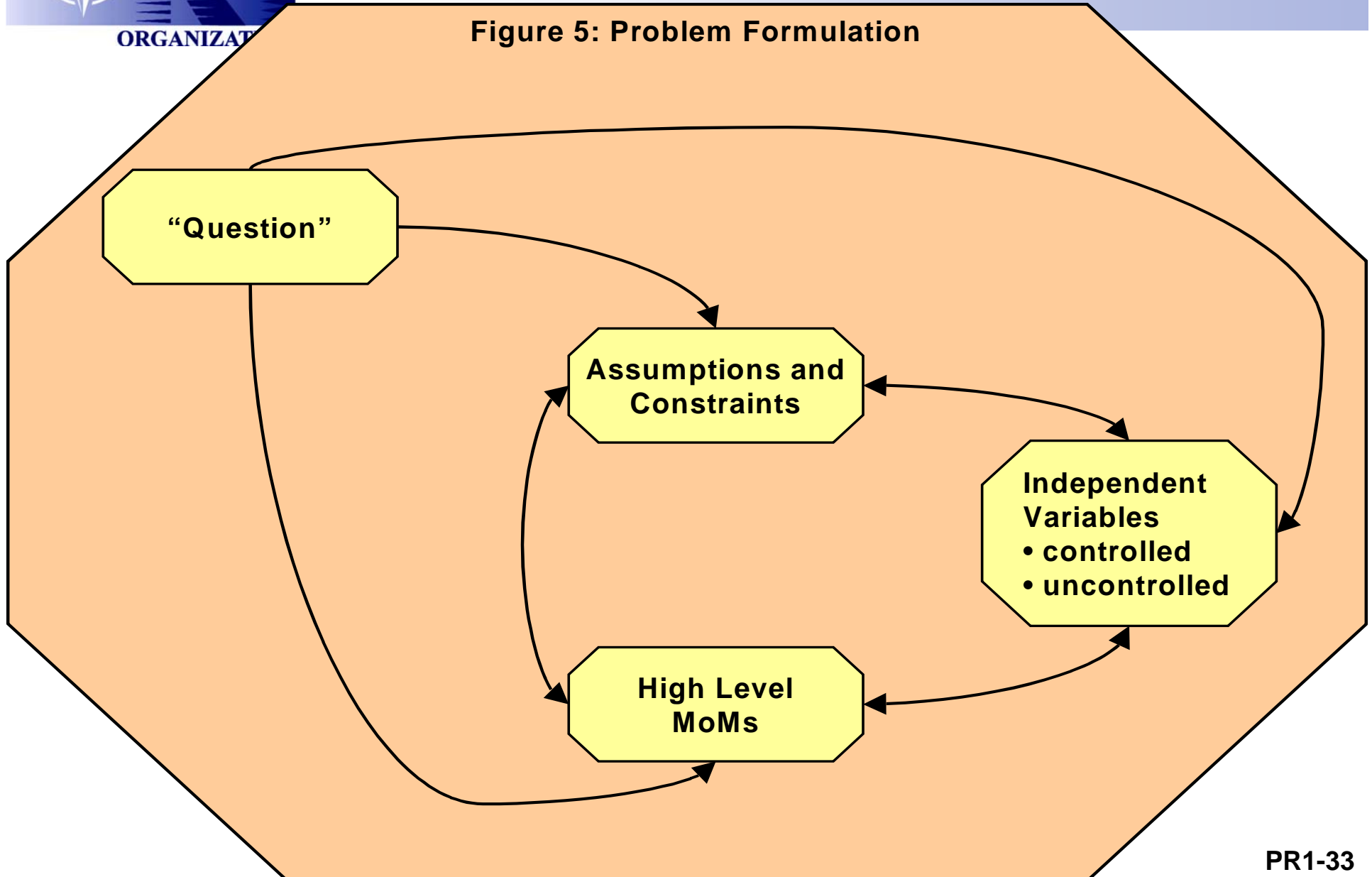
It is useful to identify, develop if necessary, and apply appropriate tools to support Problem Formulation. Representative tools and/techniques include those listed here: techniques for supporting expert elicitation, influence diagrams, causal maps, system dynamic models, and agent-based models.

Tools and approaches used for Problem Formulation must be coherent with other tools and techniques likely to be considered for the subsequent analysis, in order to produce a sensible 'multimethodology' approach to the entire problem and its solution.

This means a set of approaches which fit together across the span of the study process.

The Formulated Problem

Figure 5: Problem Formulation





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The formulation of the problem is completed when the constraints on either the independent or dependent variables have been identified. Constraints on the dependent variables represent “acceptable” thresholds or limits. For example, one could place a constraint on blue losses, time to accomplish a mission, collateral damage, or some combination of factors. Constraints on the independent variables represent either feasible or acceptable limits on such factors as human performance, C2 system performance, or even supplies. They also could represent doctrinal or legal processes that act as constraints.

The next step in the C2 assessment process is the development of a solution strategy. It should be noted that the Team is not finished with Problem Formulation at this point, but is now ready to proceed. As work progresses on the development of a Solution Strategy, it will also certainly be necessary to revisit the specification of high-level MoMs and the constraints.

Developing a Solution Strategy



Notes for Slide 36

This leads us on then to the Solution Strategy.

We will look at this from the point of view of developing a plan for the study, which takes account of the problem formulation we have just been discussing.

The Study Plan

- **The what**
 - the formulated problem
- **The how**
 - the solution strategy

Notes for Slide 38

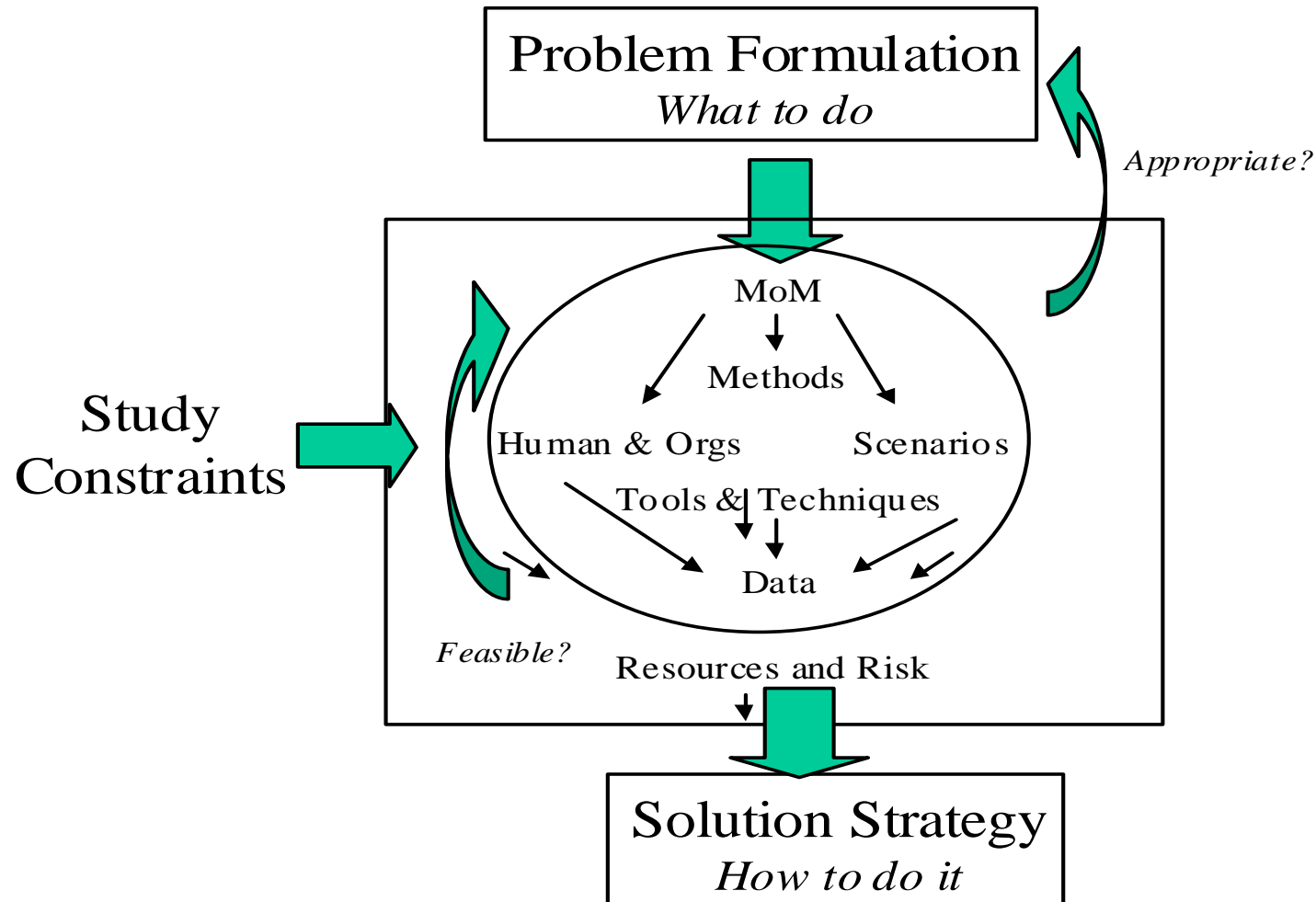
It is important that there be a conscious effort to create and follow a study plan that guides data collection and analyses and is prepared to use the insights and data that are collected to create a solution to the problem at hand. The study plan consists of two inter-related parts – the formulated problem (*the What*) and the solution strategy (*the How*).

The output of the initial Problem Formulation provides the Team with an operating definition of what needs to be done.

The output of the Solution Strategies phase provides the Team with an initial understanding of how this will be accomplished. As the project unfolds, there will usually be a significant amount of iteration that both modifies the problem formulation *and* the solution strategy. Without a study plan, it is unlikely that efforts will be properly scoped, prioritised, scheduled, and resourced.

Even if the way ahead seems clear, the articulation of a formal Solution Strategy is necessary.

From Formulation to Solution



Notes for Slide 40

We can see here what is involved in moving from a formulation problem to a solution strategy. The objective of this phase of the study is to develop a feasible approach to go from the specification of **what** is to be done to **how** it is to be done.

This involves developing an approach that will result in the Team's ability to collect the data necessary to determine the values of the Measures of Merit for specified values of independent variables.

The kinds of data collection instruments and analysis tools and techniques used will determine the resources required, the time needed, and the risks inherent in the solution approach. At all times we need to bear in mind the study constraints (time and resources available) and the key problem issues (e.g. are we measuring the right thing?).



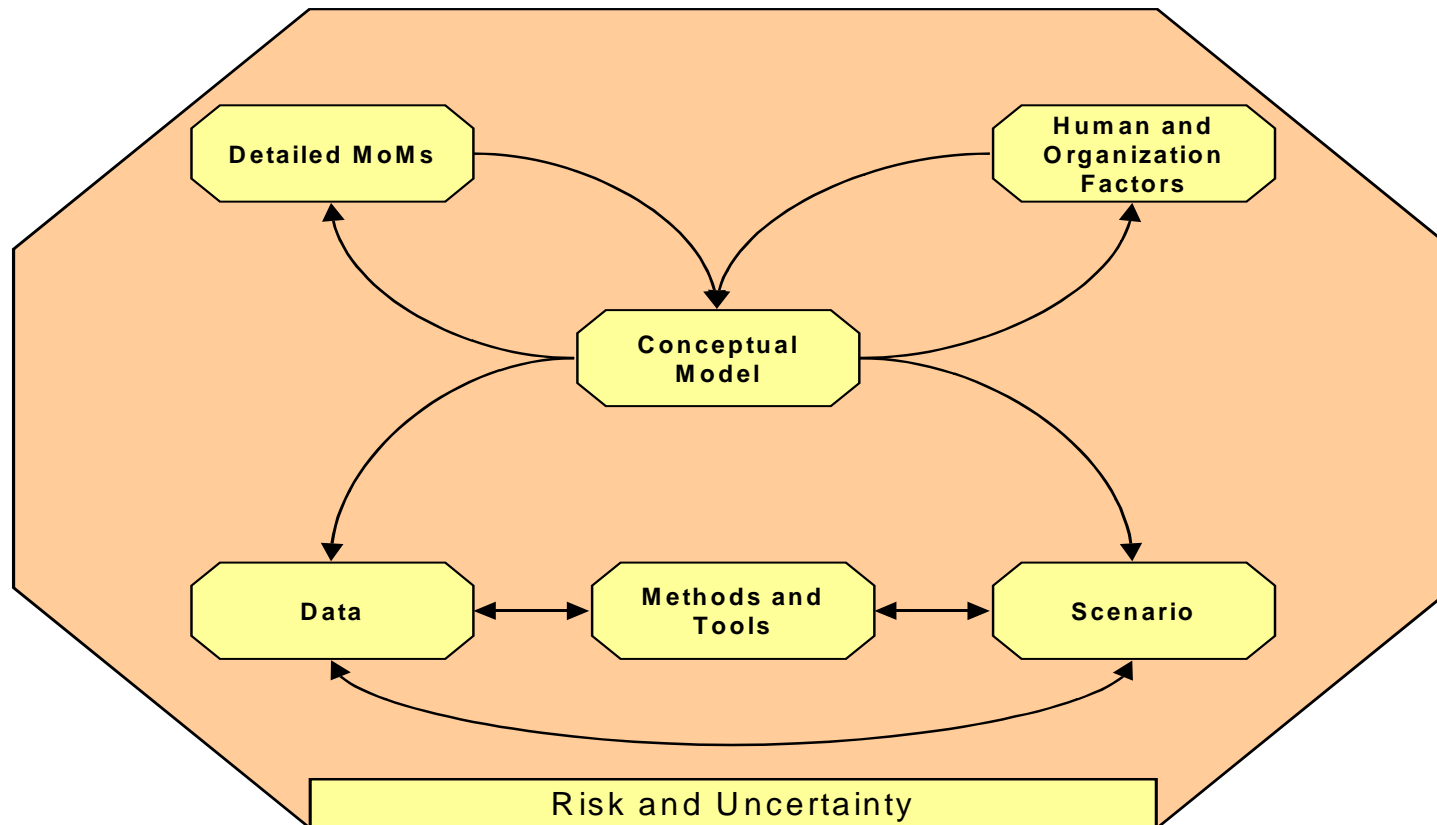
Study Constraints and Factors

- Measures of Merit
- Human Issues
- Scenarios
- Methods and Tools
- Data
- Risk and Uncertainty

Notes for Slide 42

In considering the strategy for the study, these are the key factors and constraints which need to be considered. They form separate Chapters of the new Code of Best Practice, and will be discussed in detail by other speakers, so I will not dwell further on them here.

Steps in Developing a Solution Strategy



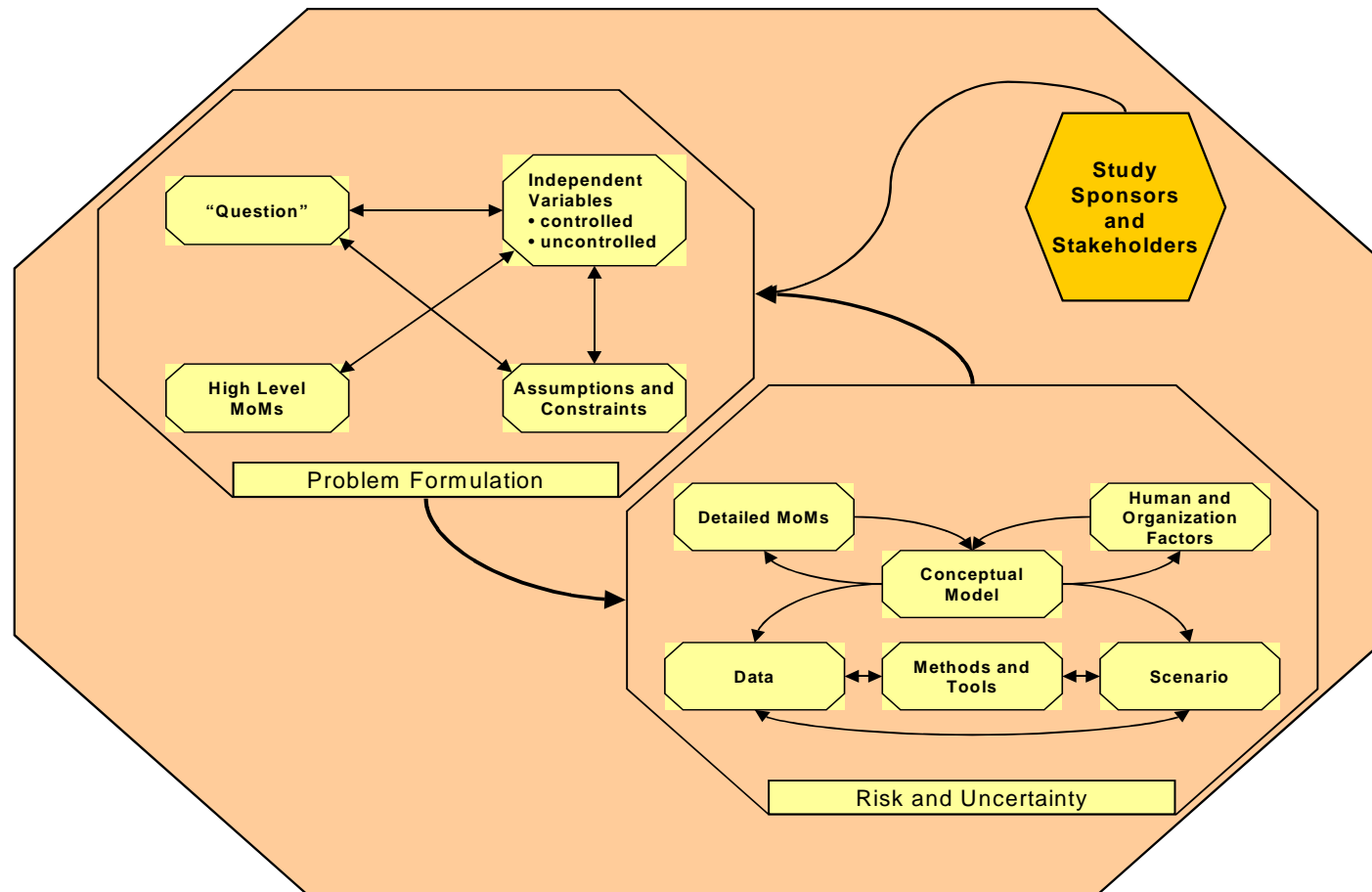
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As an initial step, the development of the set of MoM to be used in the study anchors the process that will eventually lead to a solution strategy.

This process revolves around the conceptual model that the Assessment Team builds. It is best practice to make this model explicit and have it serve as the common picture that develops a high quality of shared understanding among the Team, Sponsors, Stakeholders, and other key study participants. The initial conceptual model consists simply of the MoMs, a first cut of the hypothesised relationships among them, assumptions about variables and their relationships, and constraints. Later iterations include additional independent variables that are known or assumed to affect the values of the MoM or the nature of the relationship among them, and increasingly detailed specifications of relationships, and specific values or ranges for the independent variables.

Taken together, the detailed specification of the MoM, the development of a conceptual model including the relevant *human and organisational factors*, the specification of a set of *scenarios*, and a *data collection and analysis plan* (that consists of the methods and tools to be used) constitutes a solution strategy.

Iterative Development of the Study Plan



Notes for Slide 46

We can see here the iterative nature of the process involved in developing the Overall Study Plan.

A first order feed back loop is shown between Problem Formulation and Solution Strategy, with both processes having iterative internal processes. An analysis of Risk and Uncertainty provides the control mechanism that drives the iteration to an acceptable result.



Study Management Plan

- Detailed guidance of the project
- Time phased execution plan
- Work Breakdown Structure
- Delivery Milestones
- Etc

Notes for Slide 48

In addition to the Study Plan, the Team should also create and maintain a detailed Study Management Plan

This should cover the kind of issues described above.

Together with the broad Study Plan, this will help ensure that the study is of high technical quality, and delivers the right results at the right time.

Final Thoughts

- Effort spent 'up front' in formulating the problem will pay off later
- It is better to be approximately right than precisely wrong
- 'A theory should be as simple as possible - but no simpler' (Albert Einstein)

Notes for Slide 50

Spending more time in the initial part of the study on exploring the nature of the problem pays off later.

Firstly the study will address directly the key issues of concern to the decision makers. This creates an atmosphere of trust and engagement which helps in implementing the results of the study.

Secondly, the precise answer to the wrong problem will have no impact. This is the danger of narrowing the study down too quickly to those aspects which are easy to do.

Finally, I started with a quote, so I shall end with one. In our terms it can be expressed as: avoid unnecessary complication. Sometimes, simply formulating the problem in a way which the decision maker can full grasp is a significant step forward.

Formulating the Problem and the Strategy for Solution

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